FURTHER RESULTS FROM THE MOUNT EDGECOMBE ROOT-LABORATORY

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Introduction

The preliminary results of studies of the simultaneous growth of the roots and tops of two varieties of sugarcane, in relation to the soils and climate at the Root Laboratory, were presented to the 41st Annual Congress (1967). Full details of the laboratory, the surrounding soils and their treatment were presented in that paper (Glover[1]).

One of the results showed that disturbance of the soil below plough depth could promote faster root-growth and better root-branching than disturbance of soil to normal plough depth. The larger and more vigorous root-system which resulted from such disturbance produced correspondingly faster and more vigorous plants above ground as was shown by the data presented in the last table (Table III) of the earlier paper. However, this table referred only to the average heights of all stalks of each variety at the end of one year's growth and thus some six months before harvest. As a result the paper ended with the suggestion that the differences shown in the table might be reflected in the final yields.

It is at this point that the story of the plant responses is resumed, for the harvests have now been taken and the growth of the first ratoon crop is well under way. It starts with a discussion of the yields of the plant crop and how they are affected by root development.

Yields of the Plant Crop

The crops were planted on the 14th January, 1966, and harvested between the 24th and 28th July, 1967. They were then 18 months and a few days old.

The estimates of yield, by weight of stalk, were obtained by harvesting all the plants in 1/484-acre plots within the areas bounded by the guard rows for each variety and treatment. This amounted to two parallel 10 ft. long rows at a row spacing of 4 ft. 6 in. The plants were cut, topped and "trashed" in the usual manner. The weight and length of each stalk were measured and a random sample of the stalks from each plot analysed for sucrose content, purity, fibre, etc., at the Experiment Station's mill for experiment samples.

The results are presented in the following tables. In preparing those which refer to comparative yields, whether of cane or of sucrose, the fact that yields from small, well-tended, experimental plots are almost always higher than yields from commercial fields is taken into account. As a result the conversion of pounds per sample area to tons per acre is avoided by presenting the respective values as percentages in relation to the lowest yield as 100 per cent. Since the poorest yields of both varieties were obtained from the rain-grown crops on the undisturbed heavy clay (Dolerite), the yields of these crops were taken as 100 per cent.

Row Spacing 4 ft. 6 in.

Table I (a) shows, for each variety, the comparative yields of millable cane from the rain-grown and irrigated crops at a row spacing of 4 ft. 6 in. on the different soils and Table I (b) shows the corresponding yields of sucrose. Tables I (c) and I (d) show the respective percentages of sucrose and fibre while Table I (e) gives the corresponding purities.

Tables I (c), I (d) and I (e) show that the different soils and water régimes have not markedly affected either the sucrose or fibre content of purity of juice of each variety. As would be expected from crops cut at this time of year the variety N:Co.376 has a consistently higher sucrose content than N.50/211. It also has the higher purity of juice and the lower fibre content. So no further discussion of these tables is required.

On the other hand there are very wide differences in total yield expressed either as weights of millable cane or of sucrose. Since these are both closely correlated it will suffice if only one table is discussed, and since sucrose is the end product this can be Table I (b), which shows the relative yields by weight of sucrose.

Rain-grown—at 4 ft. 6 in. Row Spacing

This table shows that irrespective of variety the yields of sucrose from the *rain-grown* crops follow the same order. Thus the crop on the Red Sand outyields that on the T.M.S., while that on the T.M.S. is larger than on the *disturbed* Dolerite which in turn is larger than that on the *undisturbed* Dolerite.

These differences in yield also reflect the root-development in these soils. Such differences are illustrated in Fig. 1 (a), (b), (c) and (d) which shows that the Red Sand had an extensive, fine, well-branched root-system at all depths down to at least 4 ft. 8 in., the limit of our vision 1 (a). The T.M.S. had a slightly less extensive system which tended to be better developed in the top two feet of soil than at greater depths 1 (b). The *disturbed* Dolerite had a well-developed thick primary root-system which extended nearly as rapidly downward as those in the lighter soils, but secondary and subsequent branching was poorer than in the Red Sand or T.M.S. 1 (c). Finally, in the *undisturbed* Dolerite, whether irrigated or not, the primary roots were few in number in the soil immediately below plough depth and these were poorly branched until they

TABLE I
Some measurements at harvest of the plant crop at the root laboratory—1967

	Water regime	RAIN GROWN				Irrigated	
	Soil	Disturbed Red Sand	Disturbed T.M.S.	Disturbed Dolerite	Undisturbed Dolerite	Undisturbed Dolerite	
Relative weights— Millable cane	N:Co.376	200	147	127	100	171	
	N.50/211	170	138	118	100	158	(*a*)
Relative weights— Sucrose	N:Co.376	191	162	132	100	169	
	N.50/211	162	142	111	100	165	(*b*)
Actual % sucrose	N:Co.376	13.02	14.90	14.00	13.53	13.32	
	N.50/211	12.34	13.40	12.18	13.00	13.54	(*c*)
Actual % fibre	N:Co.376	10.67	11.35	10.62	10.01	11.52	
	N.50/211	15.83	13.79	13.92	14.91	15.31	(*d*)
Actual % purity	N:Co.376	86.9	91.8	89.6	89.2	89.8	
	N.50/211	81.6	87.6	85.0	87.5	87.6	(*e*)

broke through an illuvial horizon which had impeded their growth. Then they, too, branched profusely in the lighter subsoil 1 (c).

When it is remembered that the setts were clonal (Glover[1]), the soils received the same amounts of fertiliser at planting and the crops the same amount of rain during life there can be little doubt that the extent of development of the root-system, as influenced by the physical nature of the soil, was responsible for the differences in yield of the rain-grown 18-month-old plant crops.

This is particularly striking when it is also remembered that the Dolerite soil, without additional fertiliser, is inherently of higher nutrient status than either the Red Sand or Sandstone soils, and holds slightly more available water in the range between field capacity and wilting point (0.1 to 15 bar tension).

In this respect it may be labouring the obvious to say that the highest yields need not always be obtained from the soils of highest nutrient content. Unless there is adequate root-growth in such soils to tap the high fertility, yields may be as low or lower than those on lighter soils of lower nutrient status under the same water régime.

Roots are not simply sinks for photosynthate and instruments for providing tops with water and inorganic salts. They contribute elaborated materials to the shoots, as well as the unelaborated materials, in a cycle such as illustrated in Fig. 2.

Obviously, then, anything which retards root-development is likely to retard total growth and anything which promotes it is likely to promote total growth.

Lightening a soil which retards root-development merely diminishes the braking effect of the soil on the cycle and promotes the more rapid turnover which is seen as more rapid early growth of tops.

Lightening the soil is not in itself sufficient to promote higher yields. Obviously the effect of such treatment can only be detected if there is no other limiting factor during growth, such as the supply of available water. Indeed, a reduction of the water supply to the larger root-system of the plants in disturbed soils may largely nullify the results of the soil treatment. This was well illustrated by the series of events which produced the relatively small differences in yield at harvest on the *disturbed* and *undisturbed* heavy clay (Dolerite) soils, although very large differences were observed during early growth.

Some of the details of the development of the crops on both forms of this soil are shown in Table II and Fig. 3.

Table II shows for each variety on each form of the soil the comparative total stalk growth, where that on the *undisturbed* soil is taken as 100, together with the numbers of stalks in average stools of each variety at three relevant periods; shortly after the beginning of the drought (26th July), towards the end of the drought (27th September), and a fortnight after the first effective spring rains in October (1st November). Fig. 3 shows the patterns of the root development of both varieties at the corresponding times.

In July, the beneficial effect of deep disturbance

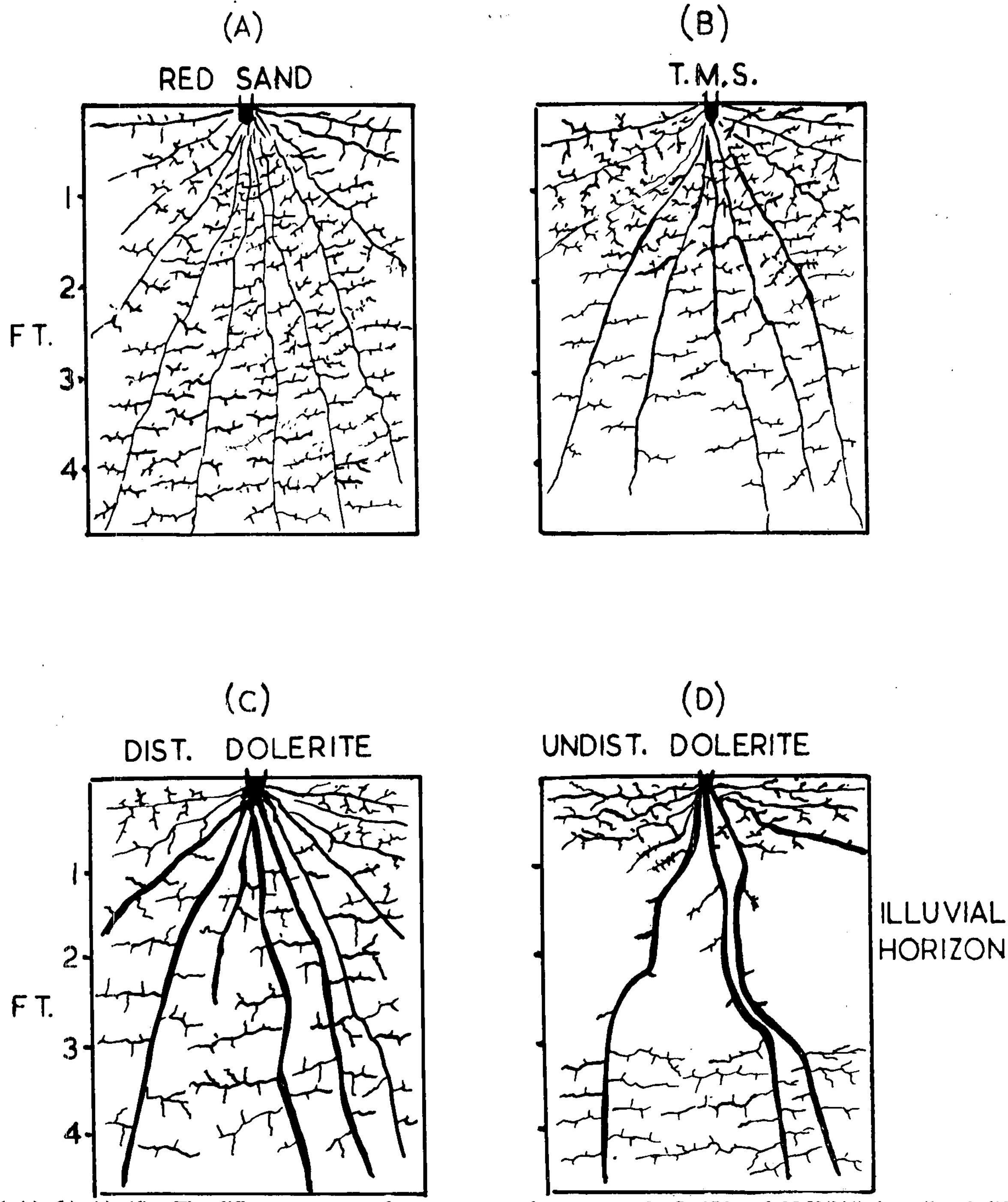

Fig. 1 (a), (b), (c), (d).—The different patterns of root-systems of sugarcane (N:Co.376 and N.50/211) in soils of different texture.

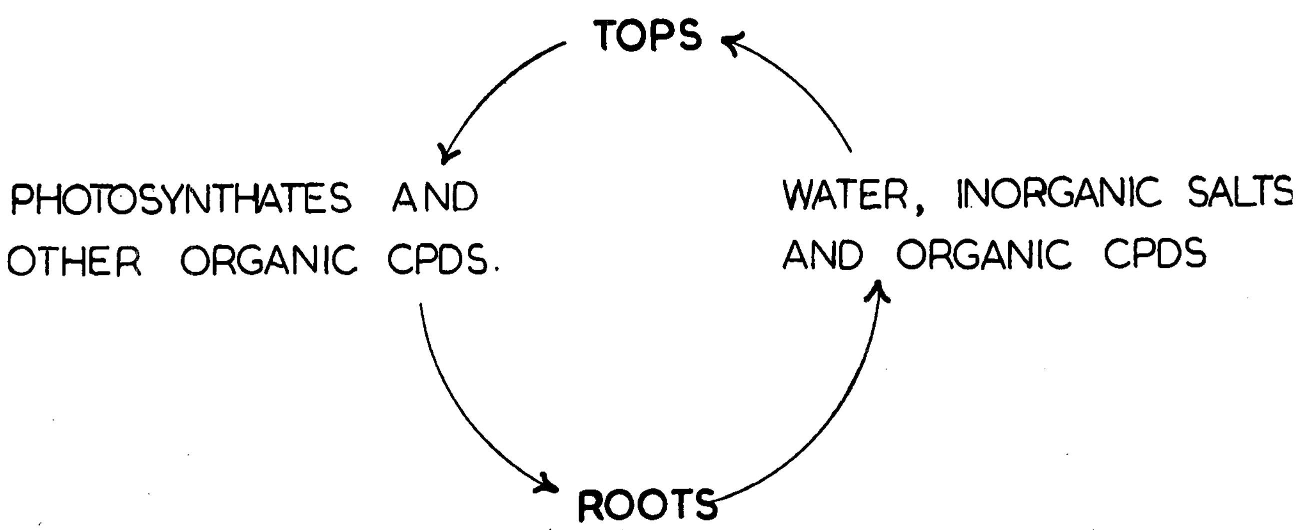

Figure 2

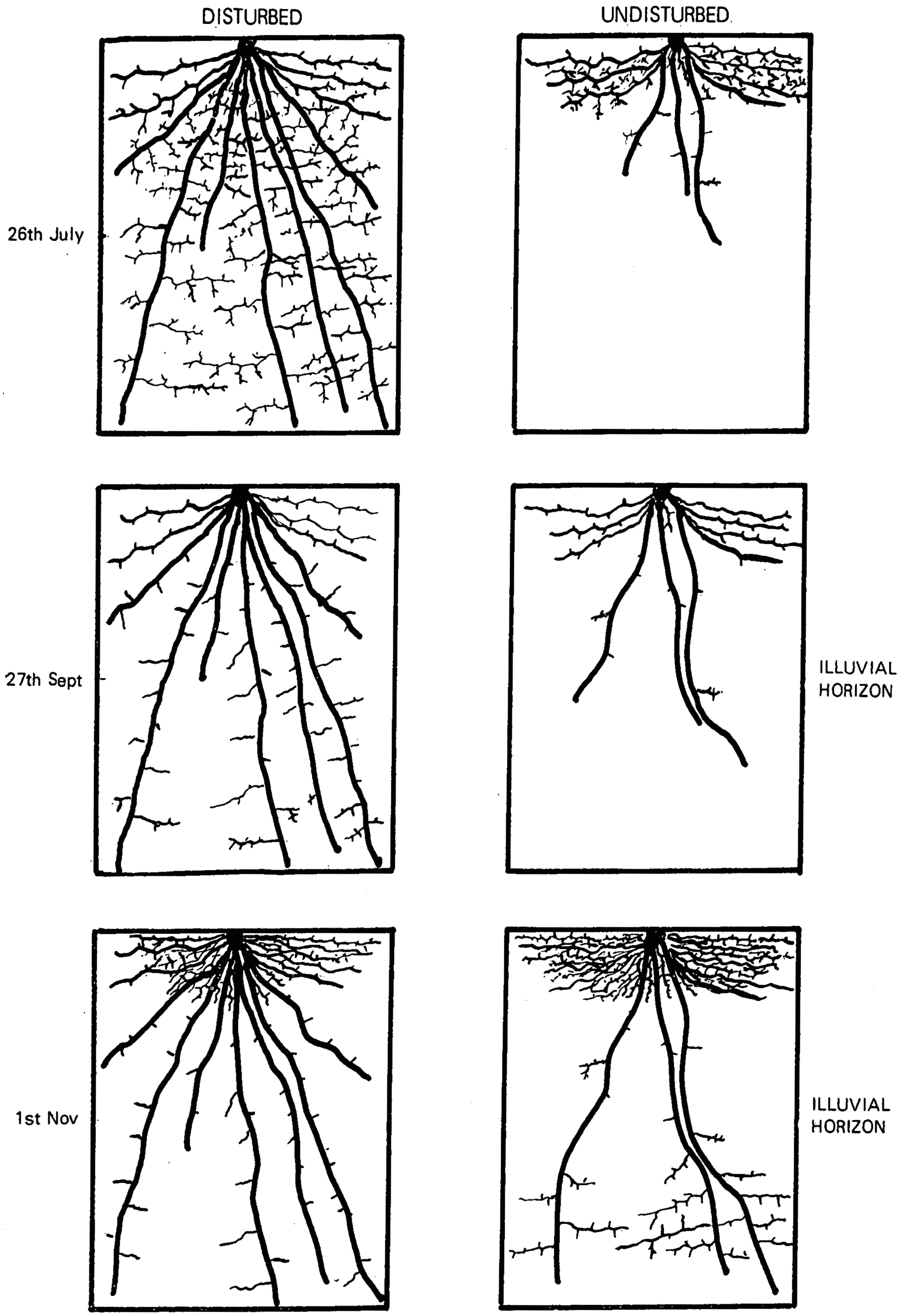

Fig. 3.—The changes in root pattern in the disturbed and undisturbed heavy clay soil before, during, and immediately after drought.

TABLE II
Measurements at the beginning and end of drought and after the first effective rain

Variety	1966 Date	Relative length of stalks Undist.	Relative length of stalks Disturbed	Average number of stalks per stool Undist.	Average number of stalks per stool Disturbed
N:Co.376	26 July	100	451	9.1	15.0
	27 Sept.	100	399	9.4	13.3
	1 Nov.	100	269	10.0	12.3
N.50/211	26 July	100	399	8.7	12.3
	27 Sept.	100	334	9.3	11.7
	1 Nov.	100	248	9.7	10.3

was well marked. Table II shows that the disturbed soil carrying only some 50 per cent more stalks than the undisturbed soil had some four to four and a half times greater length of stalk in an average stool. That this was due to better root development in the disturbed soil is shown by the patterns of the root-systems at that time (Fig. 3).

However, the large plants on the well-developed root-system in the disturbed soil quickly exhausted nearly all the available water in this soil and growth of roots and tops practically ceased. Not only did growth slow to a stop but some shoots started to die. This is reflected in the fall in number of shoots in an average stool (Table II, September).

Meanwhile the drought also affected growth of the smaller plants on the *undisturbed* soil, because the shallower root-systems exhausted water in the immediate neighbourhood of the roots and they could not grow sufficiently rapidly through the restricting illuvial horizon to obtain sufficient supplies to maintain steady growth. Nevertheless, they grew sufficiently fast to supply some water for slow growth. Further, by early September the roots penetrated through the illuvial horizon and started to grow relatively freely in the lighter moist subsoil. As a result, the crop on the *undisturbed* soil started to grow faster than the crop on the *disturbed* soil and began to overtake it (Table II, September).

When the drought was broken in mid-October the plants on *undisturbed* soil could take immediate advantage of the light rains to establish a new superficial root-system while growth continued apace below the illuvial horizon. The crop at this time was growing much faster on the *undisturbed* soil than on the *disturbed* soil. The narrowing of the gap between the two crops is shown in Fig. 4. However, as the new root system in the disturbed soil later extended more rapidly than that in the *undisturbed* soil this effect became much less pronounced.

The net result was that after the winter drought, both crops put on much the same weight of stalk whether the soil was disturbed or not. Much of this was undoubtedly due to the shallow penetration of the rains. Thus at harvest, the advantage in weight of millable cane was only 27 per cent for N:Co.376 and 18 per cent for N.50/211.

The advantage in stalk number at harvest, as shown by actual stalk counts per 20 ft. row, was only 19 per cent for N:Co.376 and 11 per cent for N.50/211.

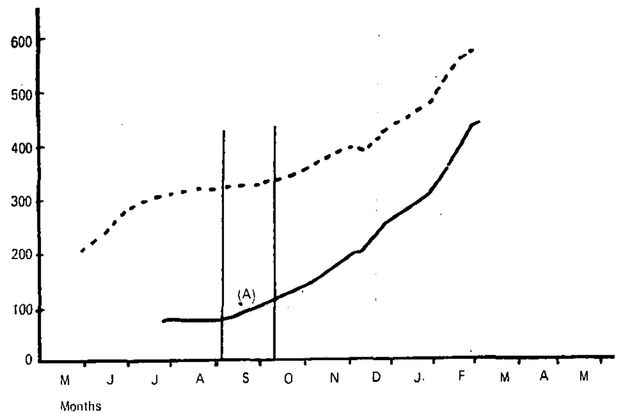

Fig. 4.—The weekly records of total length of stalks in average stools of N:Co.376 growing on undisturbed (——) and disturbed (- - - - -) heavy clay, showing the fast start of growth in the disturbed soil and the subsequent effect of drought together with the slow start in the undisturbed soil, the spurt at (A) resulting from proliferation of roots in moist soil below the illuvial horizon and the consequent narrowing of height (yield) differences.

Thus drought and its consequences had markedly reduced the effect of disturbance of this soil, and the residual advantage in yield at harvest associated with disturbance was due mainly to the extra growth when water was freely available during early development.

The details of the behaviour of the plants on the *undisturbed* soil as the roots broke through the illuvial horizon and proliferated freely in the subsoil are sufficiently interesting to warrant further description.

Figure 5 shows the relative growth rates of the tops on both the *undisturbed* and *disturbed* soil (a), as compared with the combined rainfall and evaporation data (b), and the average growth of the roots in both forms of the soil as measured at the windows of the laboratory (c).

The spurt in top growth is shown at A in the figure. It occurred only in the *undisturbed* soil and not in the *disturbed* soil. Further, as the combined rainfall-evaporation data show, it occurred during the drought. Finally, the actual measurements of

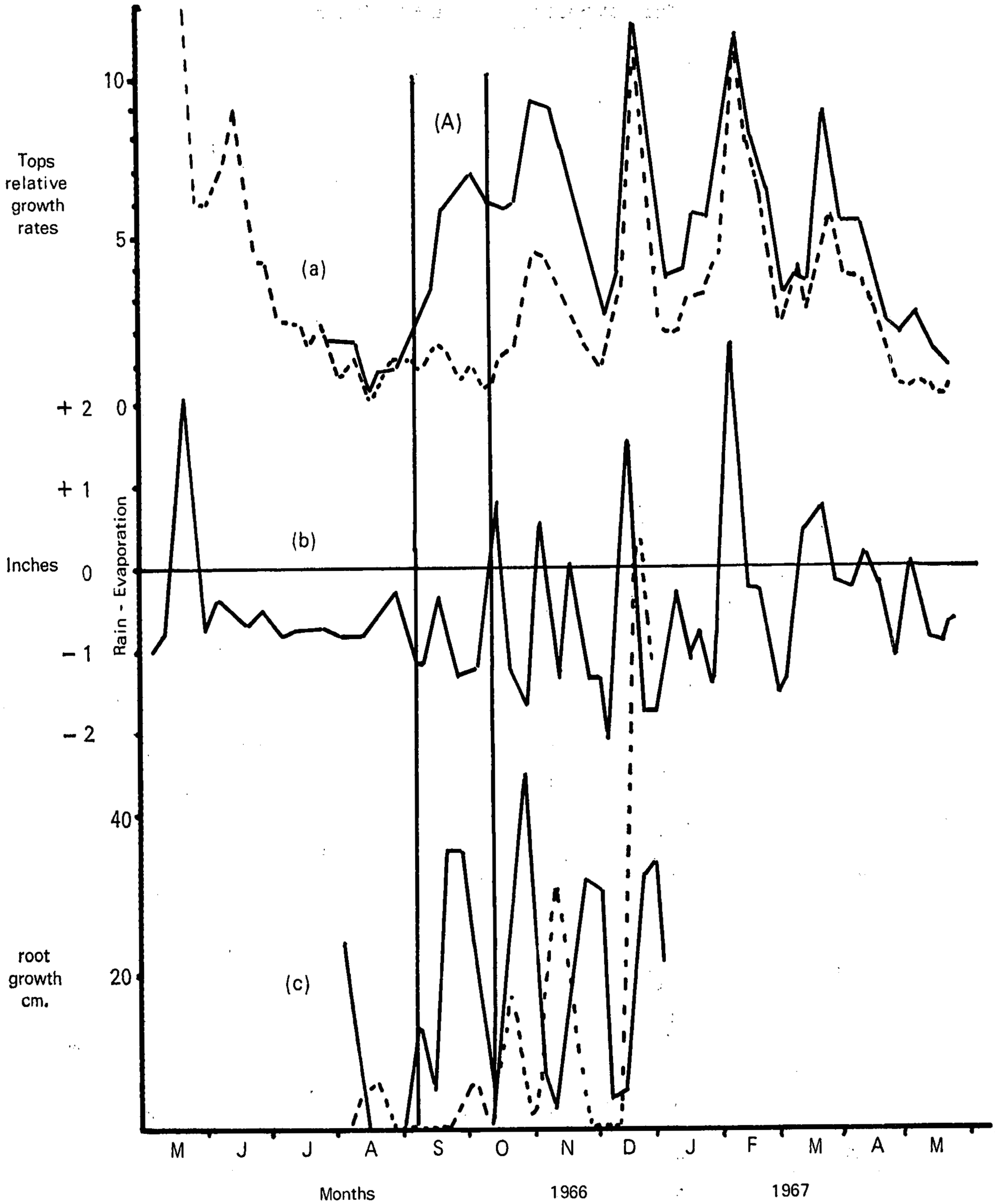

Fig. 5 (a), (b), (c):—Aspects of the spurt in growth of the crop in the undisturbed (——) and disturbed (- - - -) heavy clay soil: (a) the weekly relative growth rates, (b) the weekly differences between rainfall and evaporation, and (c) the weekly growth of roots visible between 12 and 56 inches below the surface.

root growth at this time showed that roots were growing vigorously in the *undisturbed* soil, and hardly at all in the *disturbed* soil, which was exposed to the same meteorological conditions.

As already mentioned, the root measurements refer to visible growth behind the windows, that is between 12 and 56 inches below the surface. Some new roots which could not be measured accurately also developed in the unseen layer from 4 to 12 inches below the surface. These were revealed by scraping the soil away from the base of sample plants. Such observations indicated that the development of the surface roots in both soils was at least similar in extent, with perhaps slightly better growth in the *undisturbed* soil.

The Effect of Irrigation

So far, only the comparison of yields from the rain-grown crops has been discussed. The comparisons between the yields from the *irrigated undisturbed* Dolerite and those from the rain-grown crops on the different soils are also of interest.

Only the undisturbed Dolerite was irrigated so that only one direct comparison can be made, that is with the rain-grown crop on the same soil. Table I (b) shows that the supplementary irrigation amounting to some 35 inches of water in the 18 months to harvest had a very marked effect on yield from this soil. Thus the irrigated crop produced 69 per cent more sucrose from N:Co.376 and 65 per cent more sucrose from N.50/211, a remarkably consistent, though perhaps fortuitously close result. Reference to Figure 6 shows that this was attained by a consistently higher rate of growth in height of the irrigated crop, as might be expected. However, the *rain-grown* crops on the Red Sand produced similar or even larger yields than those from the irrigated heavy clay, and yields from the T.M.S. were but little less.

In other words, rainfall was used more efficiently

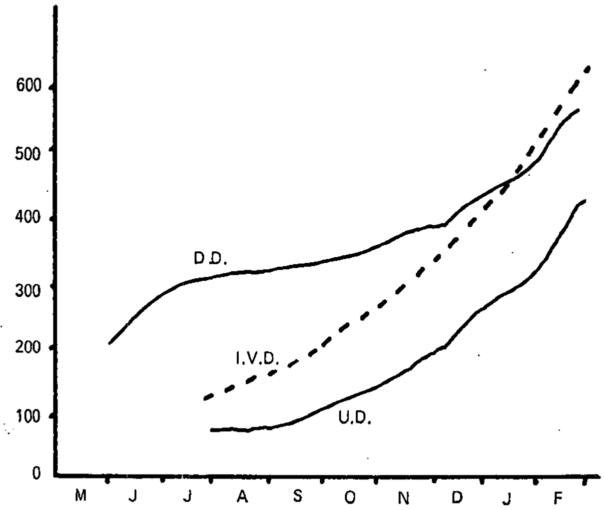

Fig. 6.—The weekly records of the total length of stalks in average stools of N:Co.376 growing on heavy clay. I.U.D. refers to irrigated undisturbed soil and D.D. and U.D. to the rain-grown crops on the disturbed and undisturbed forms of this soil.

on the sandy soils, and water may have been wasted on the undisturbed heavy soil. But it would be difficult to make a case for more than a little wastage of the water on the heavy soil. This, too, arises from the differing patterns of root development.

On the *irrigated* undisturbed heavy clay, root growth was initally sparse and slow. As a result, much water had to be applied to replenish the losses direct to air from the superficial layers of soil. This water could not have been saved for the water is needed in the immediate environs of the root and there is no simple way to get it there without loss. In the *rain-grown* crop on the same soil we have observed similar roots dry the soil to a radius of a few millimetres from their surface, then shrivel and die, although there is apparently plenty of water held nearby. The rate of transfer of water across short horizontal distances in this heavy soil was obviously too slow to prevent death from drought. As a result, the soil horizons dry slowly downwards from above, the process being hastened by the large cracks which readily develop in this soil.

Thus water is wasted in that it moves directly to the atmosphere and not through the plant. Yet this wasteful system must be maintained by irrigation in order to get consistent steady growth on this soil.

On the other hand, root development is quick and easy in moist, sandy soils and the large root-systems have correspondingly larger volumes of soils from which to draw water. Even if the upper layers are depleted during drought, the well-developed system in the deeper layers appears to be able to supply the plant with all the water it needs without marked strain. Further, even if there is a slight strain, the plants are not so severely affected that they cannot take rapid advantage of light showers to establish a new root system, even if it is only superficial in extent. Thus, in the Coastal Red Sand, which showed little or no restriction of growth due to moisture, the pattern of the active root-system changed very markedly as the soil wetted and dried. This is illustrated in Figure 7 (a), (b), (c) and (d).

Figure 7 (a) shows the pattern of the root-system as seen behind the windows of the laboratory before the onset of the winter drought, when soil moisture was freely available at all depths down to at least 78 inches (2 metres).

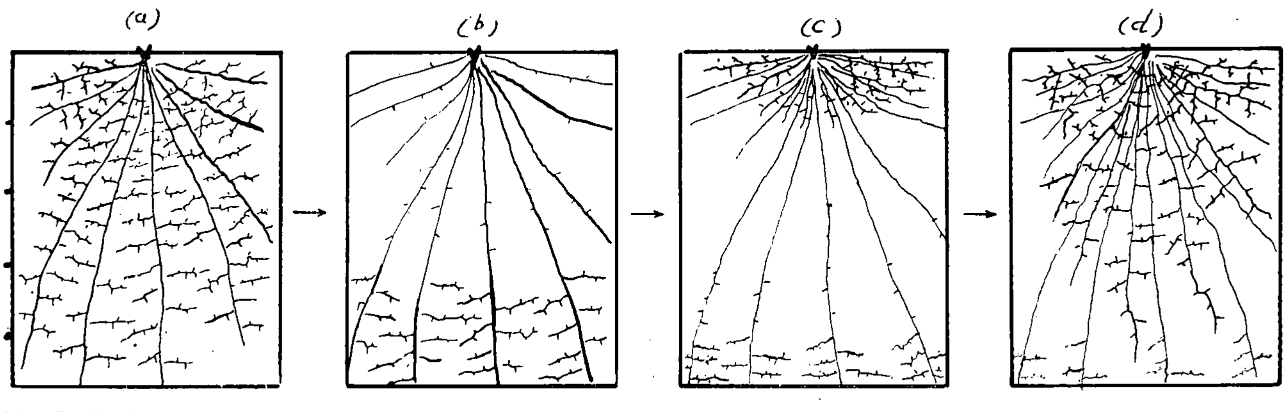

Fig. 7 (a), (b), (c), (d).—The changing distribution of active roots as a light soil dries during winter drought, (a) and (b); receives light rains in spring (c); and is replenished by heavy rain in summer (d).

During the succeeding four months (June–mid-October) of summer drought (see also Figure 3 (b)) the soil dried downwards and active roots in the dry horizons died (Figure 7 (b)). At this time the crop derived nearly all its water from the deep roots which are still active in the moister depths.

With the onset of the light spring showers, water is funnelled down the stems of the plants to create little basins of moisture around the root initials of the basal nodes Figure 7 (c).* Some of these initials are stimulated into active growth and a new superficial root system develops in the moist layers. At this time the plant derives its water from both the superficial and the very deep horizons and nothing from the dry soil which lies between. If the spring showers are followed by further drought these superficial roots may become moribund or die, as the soil dries. However, under normal circumstances a succession of light showers keep the top few inches of soil sufficiently moist to allow the plants to develop a superficial root system. Only when the heavier rains of summer recharge the profile to greater depths do the roots extend downwards once more and the original pattern reappears (Figure 7 (d)). However, the numbers of roots in the profile are less because tillers have been reduced in number from drought or overcrowding.

Close Spacing

The small close-spacing experiment using only one variety N:Co.376 on one soil, the undisturbed heavy clay, made two comparisons possible. They were between irrigation and rain-only at the close spacing and between close and wide spacing on the same soil under these two water régimes.

Table III shows the relevant data for close spacing only. The benefit of irrigation is obvious. Not only does it markedly increase yield, but, as shown in Table IV, it maintains the percentage sucrose content at the same levels as those found at wider spacing (i.e. 13.54 and 13.52 respectively). On the other hand, the percentage sucrose found in the rain-grown plants is remarkably low. Perhaps this was due to the persistent shortage of water which affected these plants throughout most of their life.

Table IV shows the relevant data for the comparison between close and wide spacing. It shows that the closer spacing has produced about twice as much yield as the wider spacing under the corresponding water régimes. The result from the irrigated, close-spaced crop was expected, because the plants never suffered from drought. But that from the rain-grown crop was unexpected. For the first 12 months of growth this crop suffered many checks. It could only grow relatively freely in the good rains of the summer of 1966/67, between December and March. So in effect the higher yield of the rain-grown, close-spaced crop is somewhat fortuitous in that it had very good, deep-penetrating rains at a critical time.

Close spacing of a rain-grown crop could not be recommended as a general practice, but there is a distinct possibility that closer spacing of irrigated crops might be worth while. A wide-row spacing is often adopted for two reasons: to permit interrow cultivation of weeds and reduce competition for water. It may be wasteful on irrigated lands, now that herbicides can control weeds.

References

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2. Glover, J., and Gwynne, M. D. (1963). Light rainfall and plant survival in East Africa. J. Ecol. 50: 111-118.
3. Wood, R. A. (1965). Rep. Exp. Stn. S. Afr. Sug. Ass., 1964-65. 96pp.

TABLE III

Yields at close spacing, only, on the heavy soil

	Rain grown	Irrigated
Relative wt. stalks	100	153
Actual % sucrose	11.36	13.52
Relative wt. sucrose	100	182

TABLE IV

The comparison between wide and close spacing on the heavy soil

		Wide spacing	Close spacing
Rain grown	Relative stalk wts.	100	205
	Actual percentage sucrose ..	13.53	11.36
	Relative sucrose wts.	100	172
Irrigated	Relative stalk wts.	100	227
	Actual % sucrose	13.54	13.52
	Relative sucrose wts.	100	227

* This is a common phenomenon and is not restricted to sugarcane. See Glover and Gwynne[2] for descriptions of similar pattern under other plants in other soils, also Wood[3] for a photograph of a later stage of this development in sugarcane.

Discussion

Mr. Wilson (in the chair): Fine roots are very important for the sustenance of the plant particularly in easily penetrable soils. So as not to destroy these surface roots we are almost certainly better off using herbicides rather than tillage implements.

Mr. Glover: Certain of our soils with illuvial horizons require some tillage but it should be done before planting. The benefit of disturbing the soil, particularly a heavy soil, lasts for some years.

Mr. du Toit: The author has reminded us of a controversy that arose in Hawaii as to whether or not roots die when the cane is cut. The problem has been partly solved but does it really matter anyway as the plant primarily needs new roots for its growth.

The radioisotope must have got to the plant by active take-up by the old roots. Radioisotopes have been put to excellent use in the root laboratory and this work must be continued.

We must be careful when we project our findings from the root laboratory. Tests must be made in the fields regarding subsoiling, etc., to see the effect on yield.

Mr. R. A. Wood: Several projects have been carried out by the Experiment Station where radioisotopes were profitably used, and they will be used where required in any future work.

Using gypsum blocks it was shown last year that old roots transport moisture, even from depths of as much as seven feet.

Mr. Aucock: How does minimum disturbance of the soil tie up with increasing the amount of oxygen in the soil?

Mr. Glover: Oxygen in the soil is measured three or four times a week and to a depth of two metres we have never reached dangerous oxygen levels in either the disturbed or undisturbed soils.

Mr. Bartlett: As there is apparently a relationship between growth above the ground and below the ground would severe pruning of roots just after cutting the cane have any deleterious effect on the plant?

Mr. Glover: This depends entirely on the time between harvest. For example, if you lose two months of the year in a twelve months harvest that represents a loss of 17% of the growth period.

Mr. Wilson: This was the essence of criticism of the Louisiana system voiced at the I.S.S.C.T. congress as with a very limited growing period the damage caused by root pruning was severe.

Mr. du Preez: I agree that the P32 could not have got to the plant through the soil but there is the possibility of exchange of P32 in the plant itself so that the tracer might be picked up in the top growth without there being a net transport of P through the root.

Mr. Pearson: Some varieties if left to grow a full twenty-four months do not ratoon well and I would like to know if this is because the old roots fade out and do not support new growth?

Mr. Glover: We do not yet have an answer to this question.

Mr. du Toit: It has been observed that cane cut in August/September ratoons well but if cut earlier, say May/June, the ratooning is not as good. This may be because when the warmer weather comes in September or October the roots have been left dormant too long.

Dr. Roth: How does Mr. Glover measure the activity or inactivity of the old dormant roots to determine whether they can translocate P32?

Mr. Glover: If we apply P32 and there is no other means for it to move and be transported to the tops we presume the roots are alive.

Dr. Roth: By applying tetrazolium chloride to the roots it can be seen quite definitely whether they are active or not.

Mr. Gosnell: Does Mr. Glover intend doing work with different varieties in connection with availability of old roots after harvest?

In Australia, particularly, there seems to be a big difference in ratooning between different varieties.

Mr. Glover: We have not yet had time to do this although we have certainly observed differences in ratooning between varieties.

Mr. K. Armstrong: Emphasis seems to be placed on old roots as being the prime factor for successful ratooning. Surely it is more a case of meristematic activity in shoot initials at the base of the cut stem.

Mr. Glover: Until that can take place the plant must survive for a few days and get some water. The old roots' main importance is for survival value in dry land farming.

Mr. Wilson: Has Mr. Glover observed new roots developing from the base of the old tillers before harvest or is this deferred until the crop is cut?

Mr. Glover: A cane plant is dynamic and is always producing new roots. However, in a ratoon crop the bulk of the root system is new.

Mr. Cownie: A dry zone round a root can apparently retard its development. In different soil types how often should one irrigate to avoid this break in moisture gradient to the roots?

Mr. Glover: I do not know the answer to that question.

Mr. Cownie: In the Eastern Transvaal we apply two immediate irrigations and then leave off in the winter months for as long as three weeks.

Mr. Glover: The length of time depends on the rate of moisture transfer through a particular soil to the roots.

Dr. Thompson: When extrapolating these results we must remember that in the particular Rydalvale Clay at the root laboratory there is an illuvial layer.

How big an area have we in the industry where soils with such an impenetrable layer exists? NCo 376 has performed equally well in a wide selection of soils under irrigation, implying that impervious soil layers are not important generally.

Mr. Hansen: What fertilizers were applied by Mr. Glover and have the nutrient values in the different root areas been analysed at different stages of growth?

Mr. Glover: The nutrient values have not been analysed.

In the plant crop 800 pounds of 2 - 3 - 2 were applied in the row and in the ratoon crop 1200 pounds of 1 - 0 - 1.

Mr. Bartlett: Has Mr. Glover any view of the effect of compaction, particularly in wet conditions, due to mechanical harvesting and does this change his attitude towards disturbing the soil in a ratoon crop?

Mr. Glover: A heavy machine on a wet soil would certainly cause compaction near the surface and it would probably be beneficial to break up the soil. Compaction is not very serious unless the soil is continuously being subjected to it.

Mr. Bartlett: If field trials are going to be put down to compare cultivation with non-cultivation one field should be compacted with, say, a loader and tandem trailer as would occur normally.

Mr. van der Meden: A trial such as suggested by Mr. Bartlett is planned at Pongola later this year.

A trial on Waldene soil at Chaka's Kraal with compaction by a tractor and infield transport did result in a decrease in yield and cultivation to a depth of 8 inches did not improve the yield of the following ratoon.

Mr. Moberley: We are currently carrying out twelve sub-soiling experiments on ratoon cane and although it is too early to give definite results, as yet there is no evidence of any benefits from sub-soiling.

We also have four experiments where we are comparing the effects of very deep ploughing, down to 50 inches, and we are subsoiling to equivalent depths but again it is too early to report results.

Mr. Morrow: The indiscriminate use of deep ploughing and deep sub-soiling could be disastrous. The intelligent use of these techniques coupled with all-round improved management should be the aim.